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RESEARCH MEMORANDUM

TESTS OF THE NACA 64-010 AND 64A010 AIRFOIL SECTIONS AT HIGH SUBSONIC MACH NUMBERS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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TESTS OF THE NACA 64-010 AND 64A010 AIRFOIL SECTIONS AT HIGH SUBSONIC MACH NUMBERS

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SUMMARY

Aerodynamic characteristics of the NACA 64-010 and 64A010 airfoil sections have been determined from wind-tunnel tests at Mach numbers from 0.3 to 0.9. The corresponding Reynolds number variation was from approximately 1×10^6 to 2×10^6. Comparisons are made which indicate the only significant differences in the characteristics of the two sections to be a consistently greater lift-curve slope, and an approximately 10-percent greater maximum section lift coefficient at Mach numbers above 0.7 for the NACA 64-010 airfoil section. These differences are attributed to the difference in trailing-edge angles (approximately 6° and 12° for the NACA 64-010 and 64A010, respectively) of the airfoil sections.

INTRODUCTION

In practical applications it has often been found desirable for structural convenience to remove the cusp from the trailing-edge portion of the profile of NACA 6-series airfoils. To satisfy the demand for an airfoil section retaining the characteristics of the NACA 6-series sections but with a straight-sided after portion, the NACA 6A-series airfoil sections were derived. (See reference 1.) The trailing-edge angles for the latter type airfoils are considerably greater than for the NACA 6-series, and questions have been raised concerning the effects of this difference on the variation with Mach number of the aerodynamic characteristics of the two types of airfoil sections. The present investigation of the NACA 64-010 and 64A010 airfoil sections was undertaken in the Ames 1- by 3-1/2-foot high-speed wind tunnel to provide such information for 10-percent-chord-thick profiles.

NOTATION

a_o section lift-curve slope, per degree

c_d section drag coefficient

[redacted]

c_l section lift coefficient

$c_{l_{max}}$ maximum section lift coefficient

$c_{m_{c/4}}$ section pitching-moment coefficient about the quarter-chord point

M Mach number

α_o section angle of attack, degrees

APPARATUS AND TESTS

The tests were conducted in the Ames 1- by 3-1/2-foot high-speed wind tunnel, a low-turbulence, two-dimensional-flow wind tunnel.

Six-inch chord models of the NACA 64-010 and 64A010 airfoil sections were constructed of aluminum alloy according to the coordinates of table I. The difference in profile of the two sections can be seen in figure 1.

The models completely spanned the 1-foot dimension of the tunnel test section. Sponge-rubber gaskets compressed between the model ends and the tunnel walls were used to preserve two-dimensional flow by preventing end leakage.

Lift, drag, and pitching moment about the airfoil quarter-chord position were measured simultaneously at Mach numbers ranging from 0.3 to 0.9 for the models at angles of attack increasing by increments of 1° or 2° from -2° to 12°. The range of angles was sufficient to encompass the lift stall up to a Mach number of 0.8. The Reynolds numbers varied from approximately 1×10^6 at the lower Mach numbers to approximately 2×10^6 at the higher Mach numbers.

Lift forces and pitching moments were determined by a method similar to that described in reference 2 from measurements of the pressure reactions on the tunnel walls of the forces on the airfoils. Drag forces were determined from wake-survey measurements made with a rake of total-head tubes.

RESULTS AND DISCUSSION

Section lift, drag, and quarter-chord pitching-moment coefficients are presented as functions of Mach number at constant angles of attack in figures 2, 3, and 4, respectively, for the NACA 64-010 and 64A010 airfoil sections. The angles of attack indicated represent nominal values only, and are subject to a possible experimental error amounting to as much as 0.1°. Corrections for tunnel-wall interference by the methods of reference 3 have been applied to the data. The broken lines on the figures serve to indicate the region of possible influence of wind-tunnel choking effects on the results.

Lift Characteristics

The variations of section lift coefficient with Mach number are seen from figure 2 to be very similar for the NACA 64-010 and 64A010 sections. The asymmetry of the curves of figure 2(b) about the zero lift line is believed to be due to a consistent error in the setting of the model angle of attack. The Mach numbers for lift divergence and the variations of lift coefficient above the lift-divergence Mach numbers are virtually the same for the two profiles at a given angle of attack.

The principal difference in the lift characteristics of the NACA 64-010 and 64A010 airfoil sections is indicated in figure 5, depicting the variation of lift coefficient with angle of attack at constant Mach numbers for the two sections. At Mach numbers greater than 0.7, the maximum lift coefficient is approximately 10 percent greater for the NACA 64-010 than for the NACA 64A010 airfoil section. The difference is more clearly indicated in figure 6, which illustrates the variation of maximum section lift coefficient with Mach number for the two profiles.

The lift-curve slope variations with Mach number are presented in figure 7 for the two airfoil sections. The slope for the NACA 64-010 section is consistently greater than that for the NACA 64A010 section. A similar result has been observed in tests of 12-percent-chord thick sections and has been attributed to a difference in profile trailing-edge angle. The trailing-edge angles for the NACA 64-010 and 64A010 sections are approximately 6° and 12°, respectively. The results of as yet unpublished tests on the effects of systematic variation of trailing-edge angle on the characteristics of an airfoil section support the belief that the differences observed in the present investigation in both the lift-curve slope and the maximum lift coefficients at Mach numbers above 0.7 are due to the difference in trailing-edge angle.

Drag Characteristics

There is no sensible difference in the variation of section drag coefficient with Mach number for the NACA 64-010 and 64A010 airfoil sections (fig. 3). The drag-divergence Mach numbers at the lowest lift coefficients are slightly higher for the NACA 64A010 section, but the rate of rise of drag coefficient with Mach number is the same for the two profiles.

Inspection of figure 8 reveals some differences in the variation of drag coefficient with lift coefficient. At Mach numbers above 0.65, the drag coefficient for the NACA 64-010 airfoil section increases less rapidly with lift coefficient than does that for the NACA 64A010 section. The minimum drag coefficients are somewhat lower for the latter section, however.

Pitching-Moment Characteristics

The respective variations of pitching-moment coefficient with Mach number at constant angles of attack (fig. 4), and with lift coefficient at constant Mach numbers (fig. 9) are essentially the same for the NACA 64-010 and 64A010 airfoil sections.

CONCLUDING REMARKS

From the results of wind-tunnel tests of the NACA 64-010 and 64A010 airfoil sections at Mach numbers from 0.3 to 0.9, it is concluded that the lift characteristics of the two airfoil sections differ sensibly only in the slope of the lift curve and in the magnitude of the maximum lift coefficient at Mach numbers above 0.7. The lift-curve slope for the former is consistently greater than that for the NACA 64A010 airfoil section. The maximum lift coefficient at Mach numbers above 0.7 is approximately 10 percent greater for the NACA 64-010 section. These differences are attributable to the smaller trailing-edge angle of the latter section.

The drag and pitching-moment characteristics of the two sections are, in general, the same. A slightly lower minimum drag coefficient at Mach numbers above 0.6 for the NACA 64A010 airfoil section is balanced by a more favorable variation of drag coefficient with lift coefficient for the NACA 64-010 section.

Ames Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Moffett Field, Calif.

REFERENCES

1. Loftin, Laurence K., Jr.: Theoretical and Experimental Data for a Number of NACA 6A-Series Airfoil Sections. NACA TN 1368, 1947.

2. Abbott, Ira H., von Doenhoff, Albert E., and Stivers, Louis S., Jr.: Summary of Airfoil Data. NACA ACR L5C05, 1945.

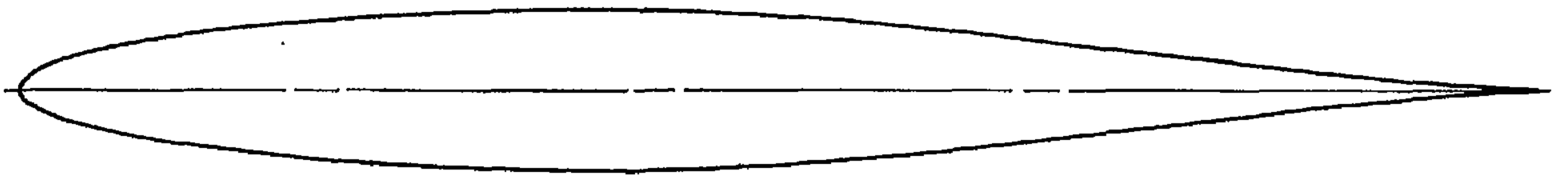
3. Allen, H. Julian, and Vincenti, Walter G.: Wall Interference in a Two-Dimensional-Flow Wind Tunnel, with Consideration of the Effect of Compressibility. NACA Rep. 782, 1944.

TABLE I. – AIRFOIL COORDINATES

[Stations and ordinates in percent of wing chord]

NACA 64-010	
Station	Upper or lower surface ordinate
0	0
.5	.820
.75	.989
1.25	1.250
2.5	1.701
5.0	2.343
7.5	2.826
10	3.221
15	3.842
20	4.302
25	4.639
30	4.864
35	4.980
40	4.988
45	4.843
50	4.586
55	4.238
60	3.820
65	3.345
70	2.827
75	2.281
80	1.722
85	1.176
90	.671
95	.248
100	0
L.E.Radius 0.720; Percent c	

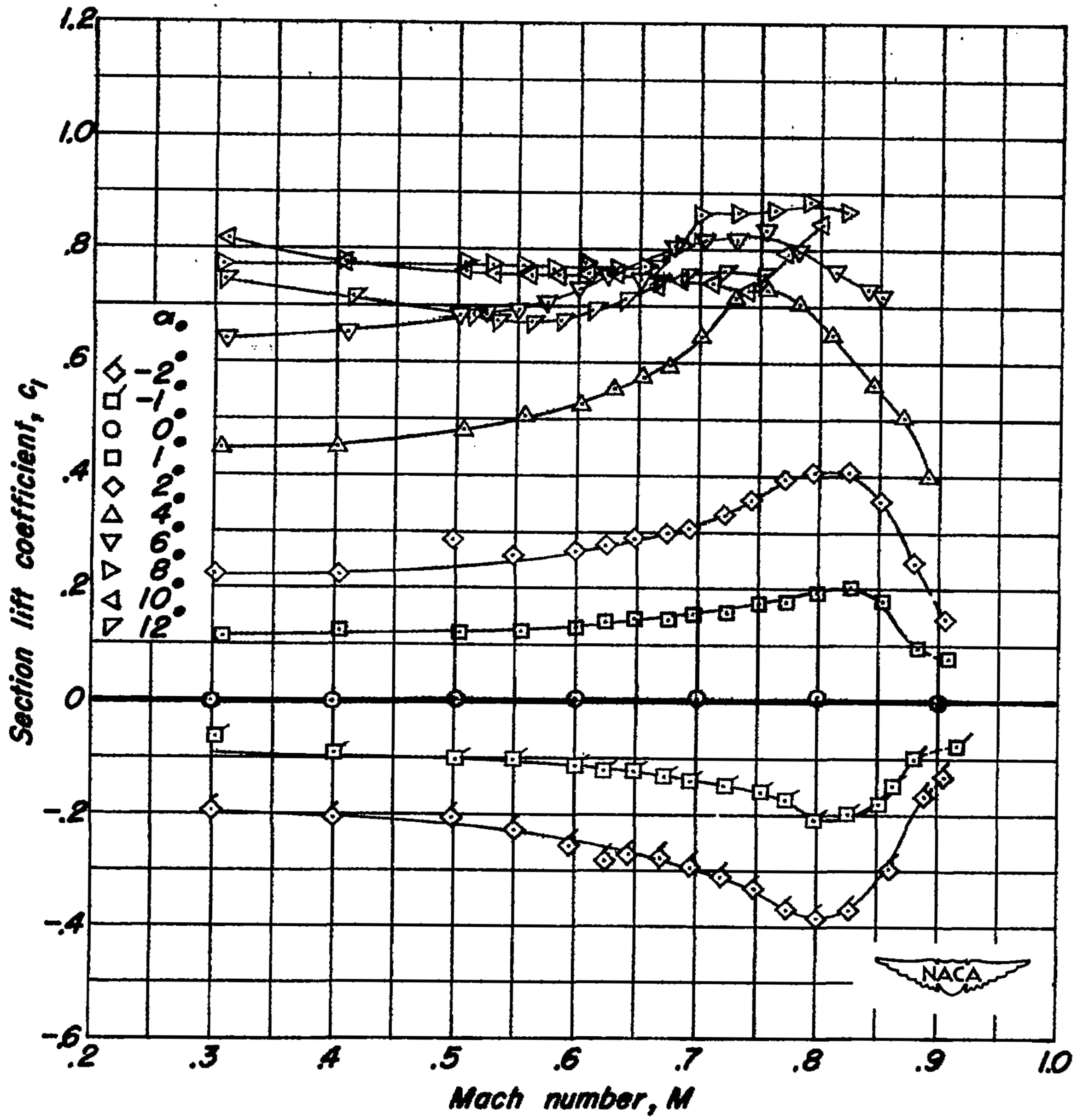
NACA 64A010	
Station	Upper or lower surface ordinate
0	0
.5	.804
.75	.969
1.25	1.225
2.5	1.688
5.0	2.327
7.5	2.805
10	3.199
15	3.813
20	4.272
25	4.606
30	4.837
35	4.968
40	4.995
45	4.894
50	4.684
55	4.388
60	4.021
65	3.597
70	3.127
75	2.623
80	2.103
85	1.582
90	1.062
95	.541
100	.021
L.E.Radius 0.687; T.E.Radius 0.023; Percent c	



(a) NACA 64-010.

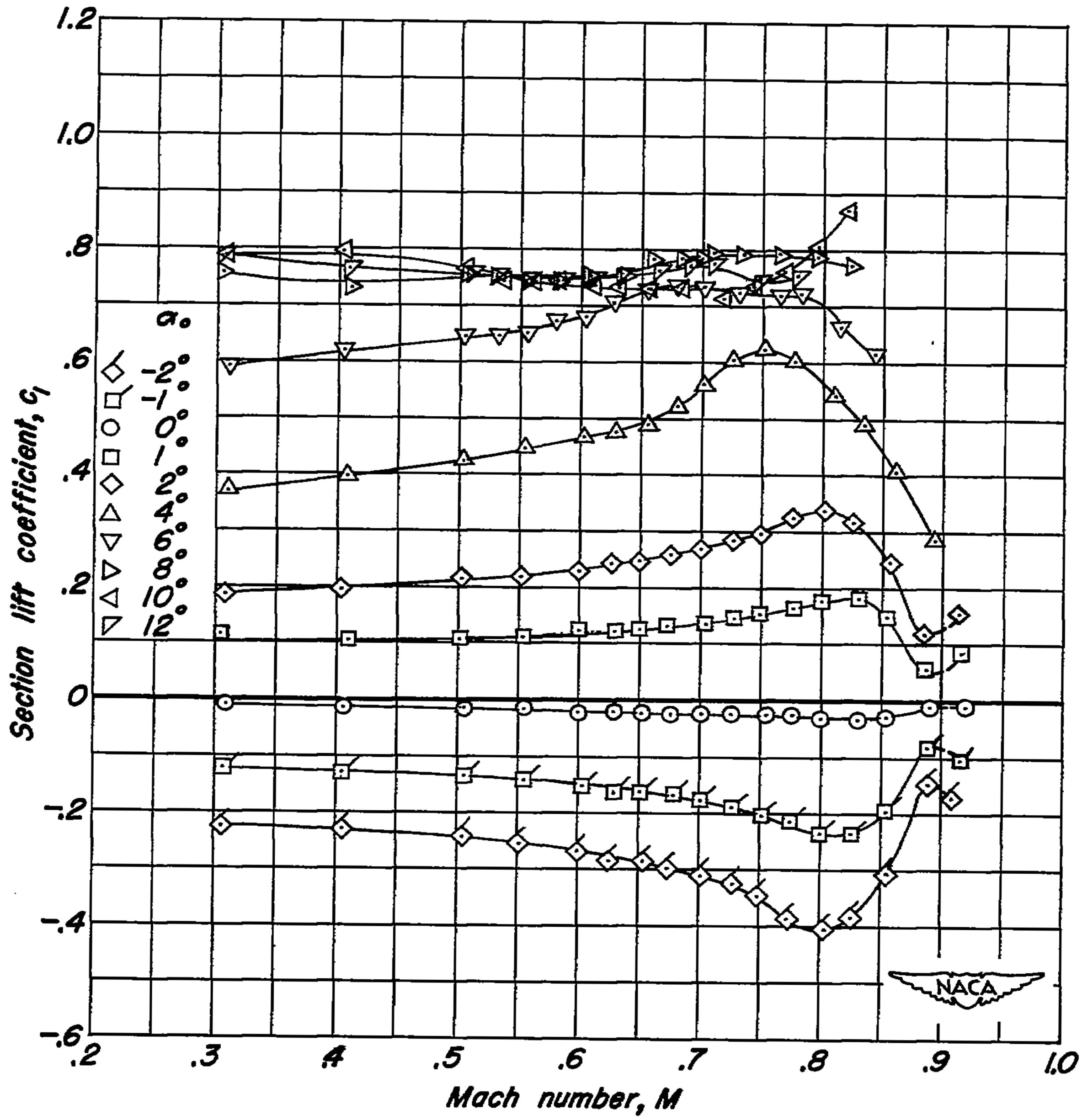
(b) NACA 64A010.

Figure 1.- Airfoil profiles.



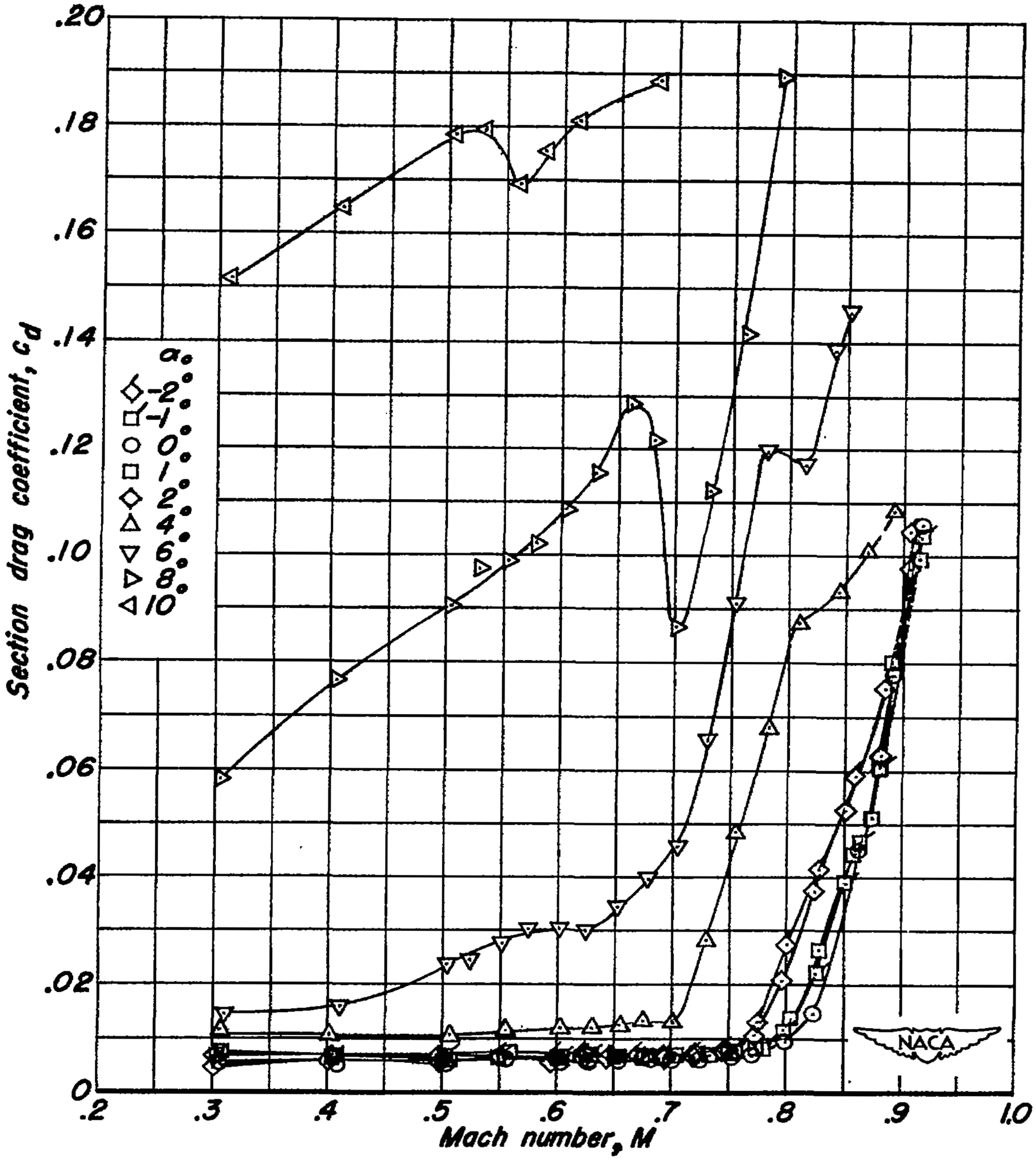
(a) NACA 64-010.

Figure 2.– The variation of section lift coefficient with Mach number at various angles of attack.



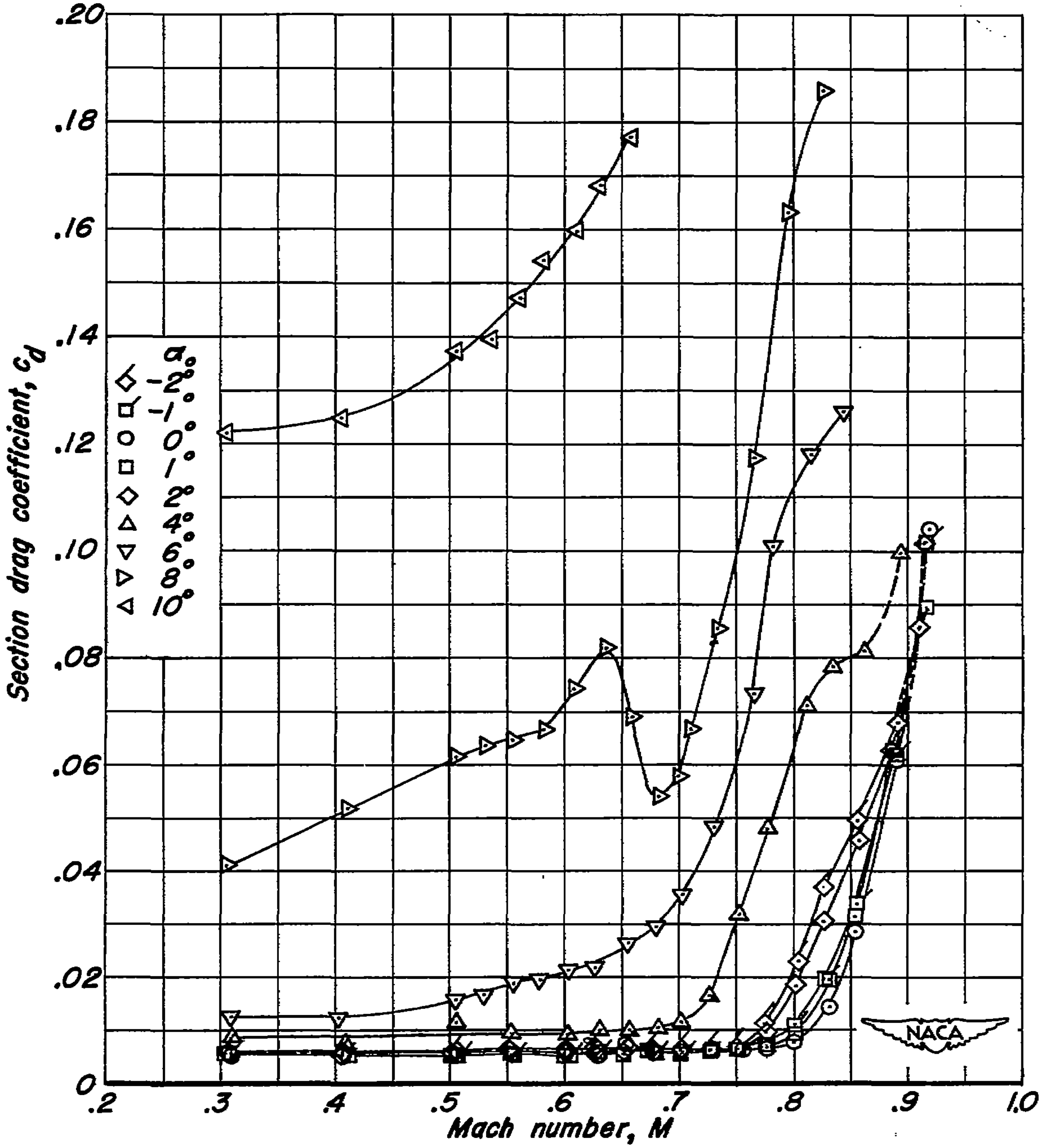
(b) NACA 64A010.

Figure 2. — Concluded.



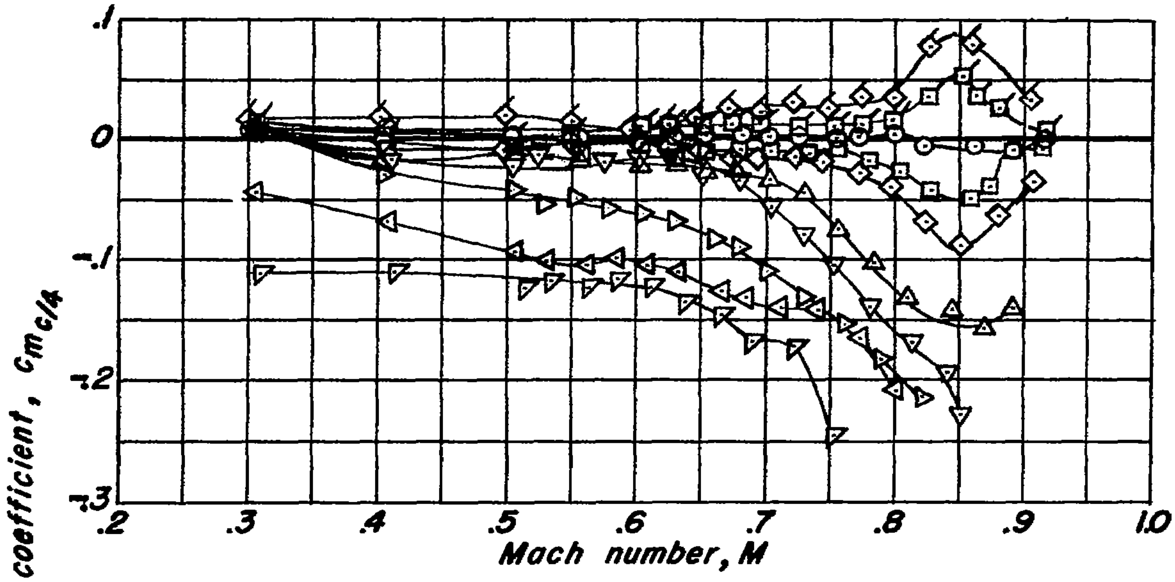
(a) NACA 64-010.

Figure 3.— The variation of section drag coefficient with Mach number at various angles of attack.

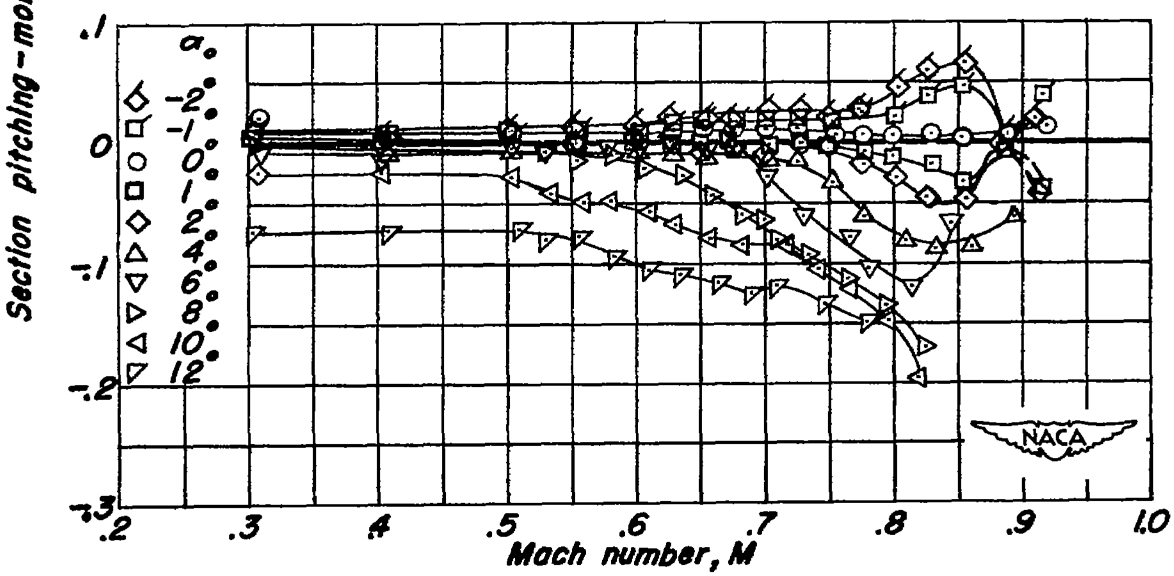


(b) NACA 64A010.

Figure 3.— Concluded.

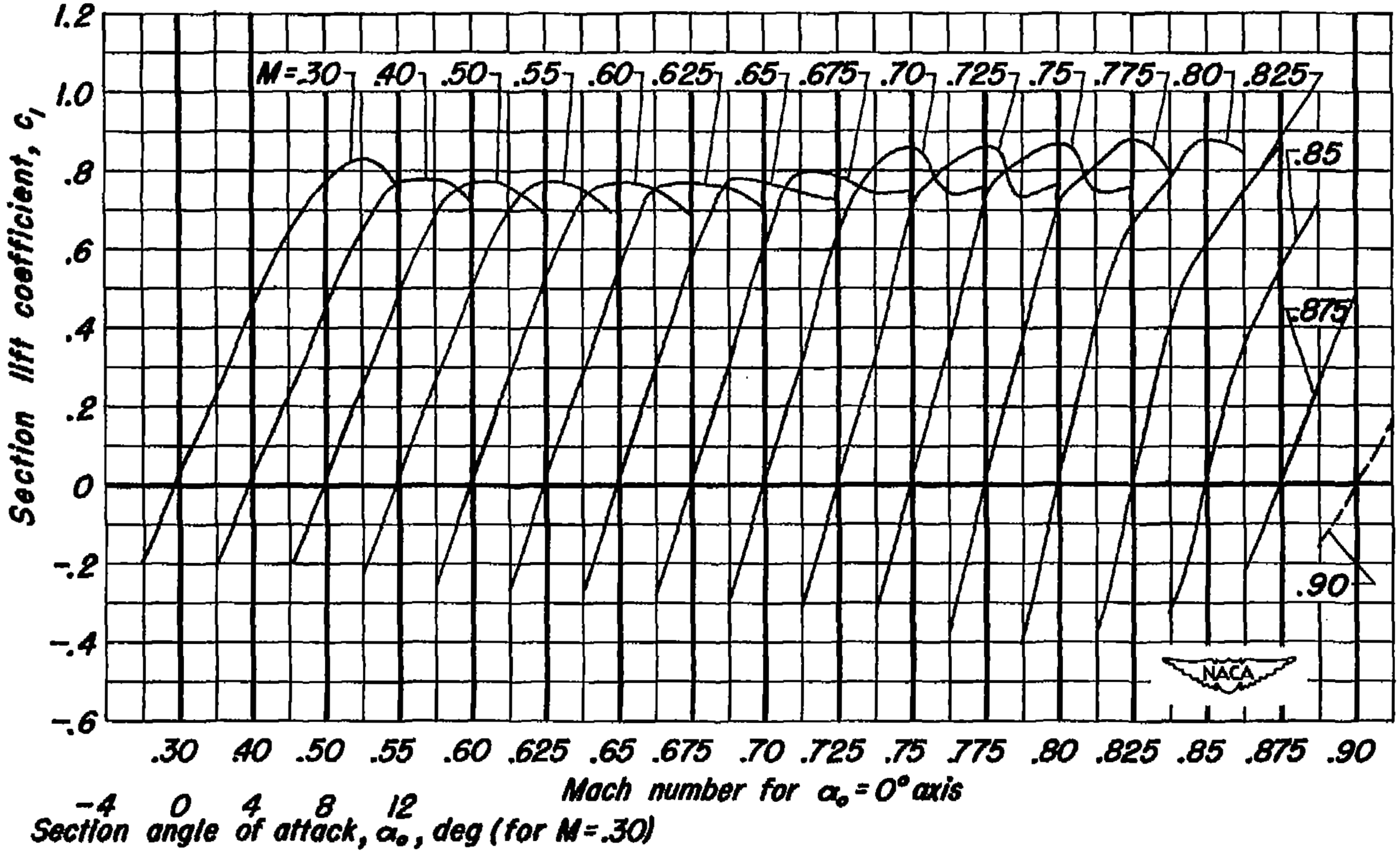


(a) NACA 64-010.



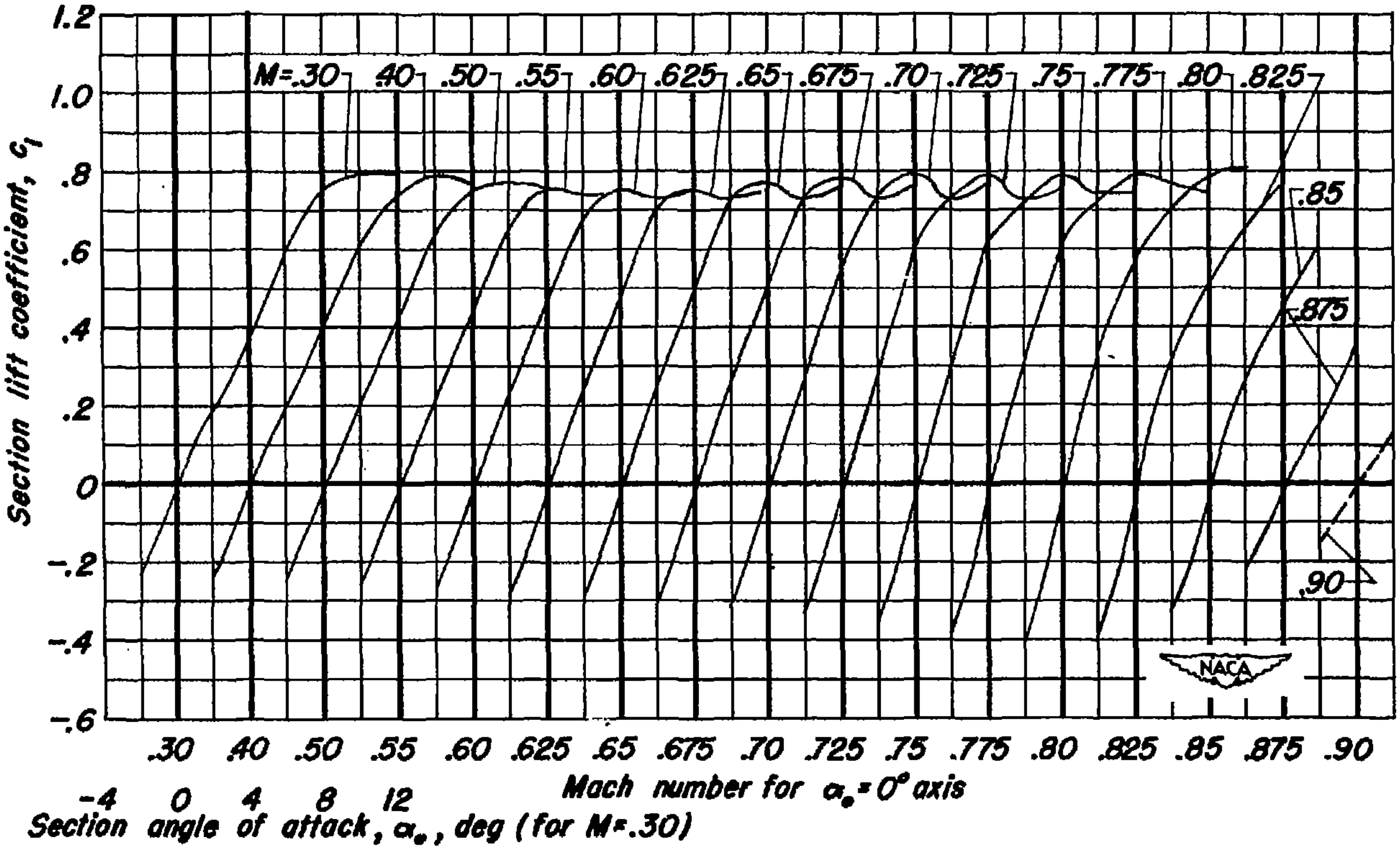
(b) NACA 64A010.

Figure 4.— The variation of section pitching-moment coefficient with Mach number at various angles of attack.



(a) NACA 64-010.

Figure 5. — The variation of section lift coefficient with angle of attack at various Mach numbers.



(b) NACA 64A010.

Figure 5. — Concluded.

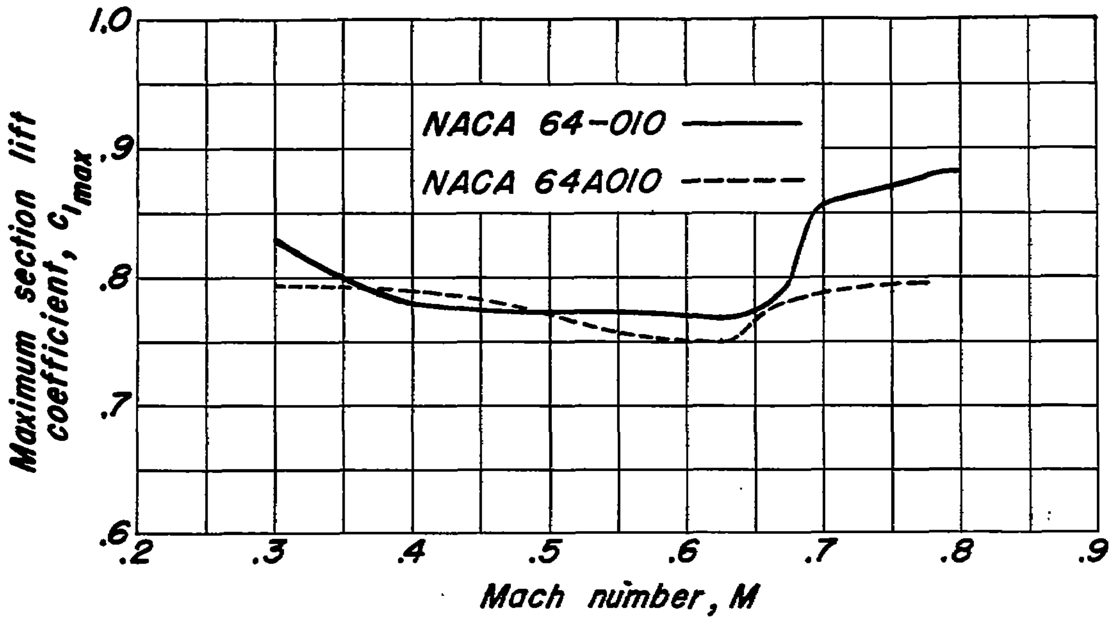


Figure 6. — The variation of maximum section lift coefficient with Mach number for the NACA 64-010 and the NACA 64A010 airfoils.

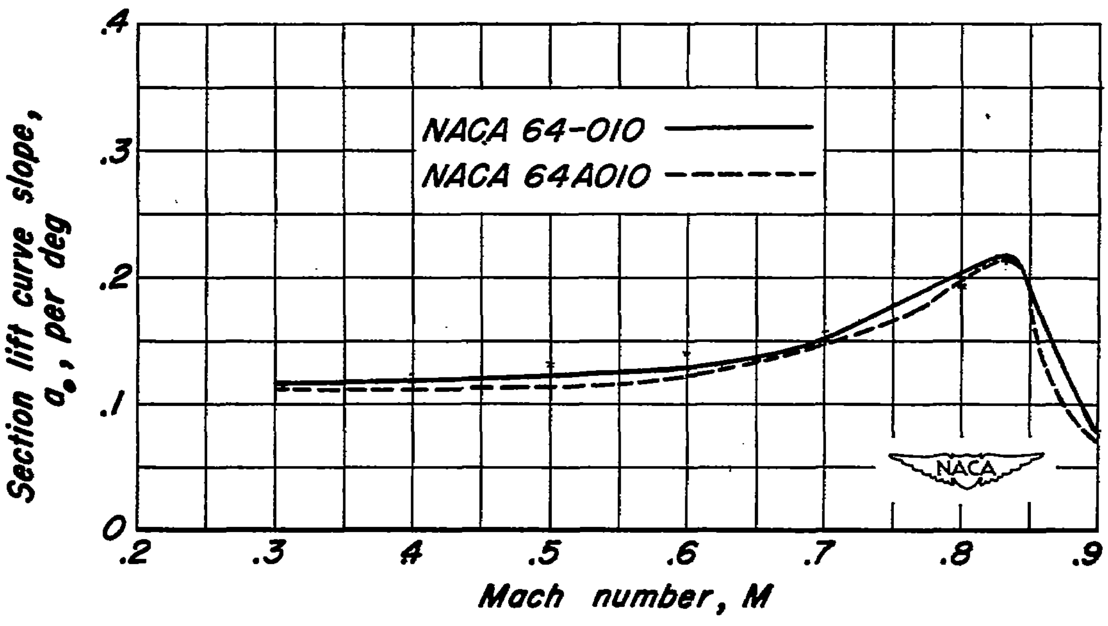
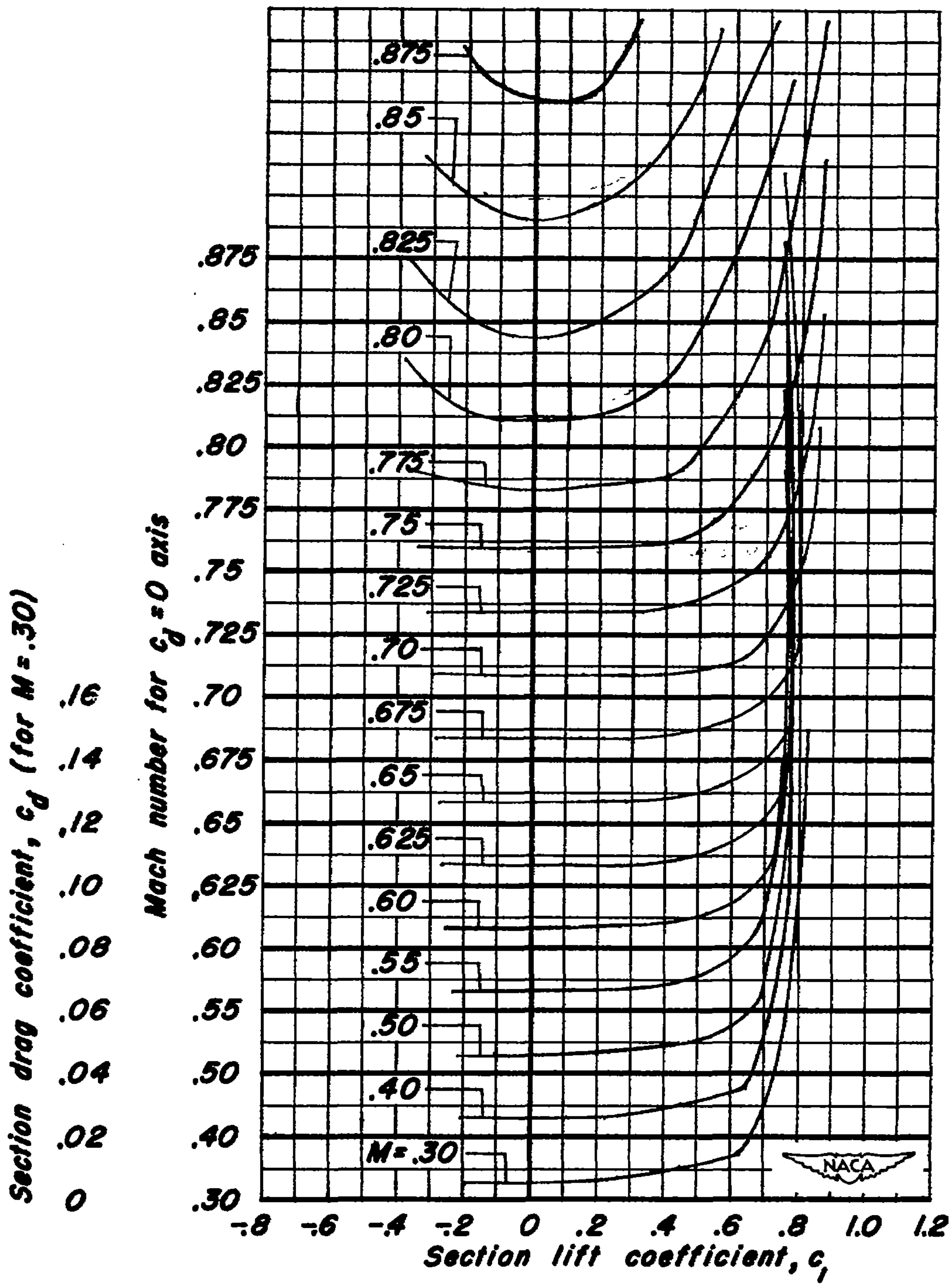
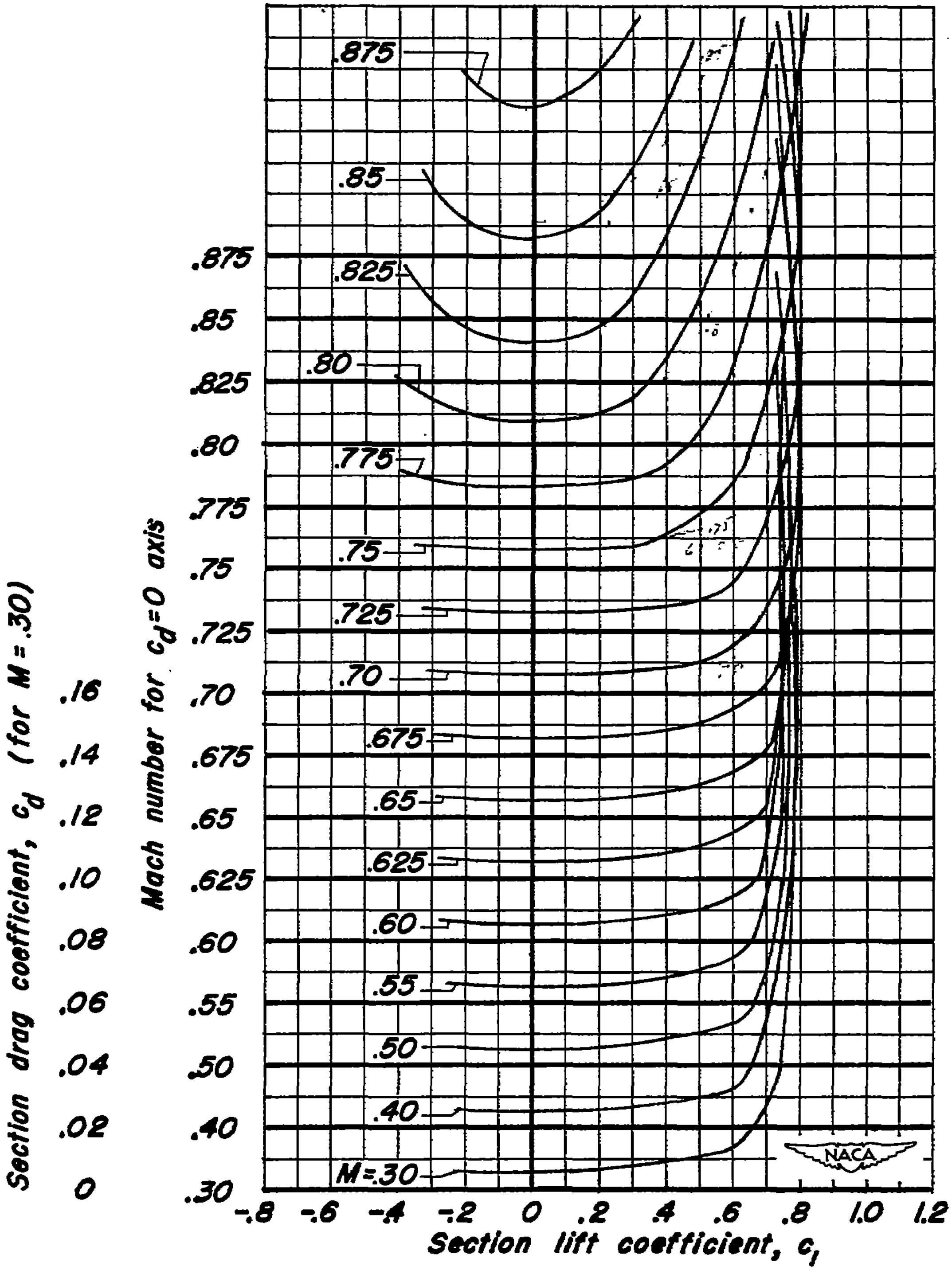


Figure 7. — The variation of section lift-curve slope with Mach number for the NACA 64-010 and the NACA 64A010 airfoils.



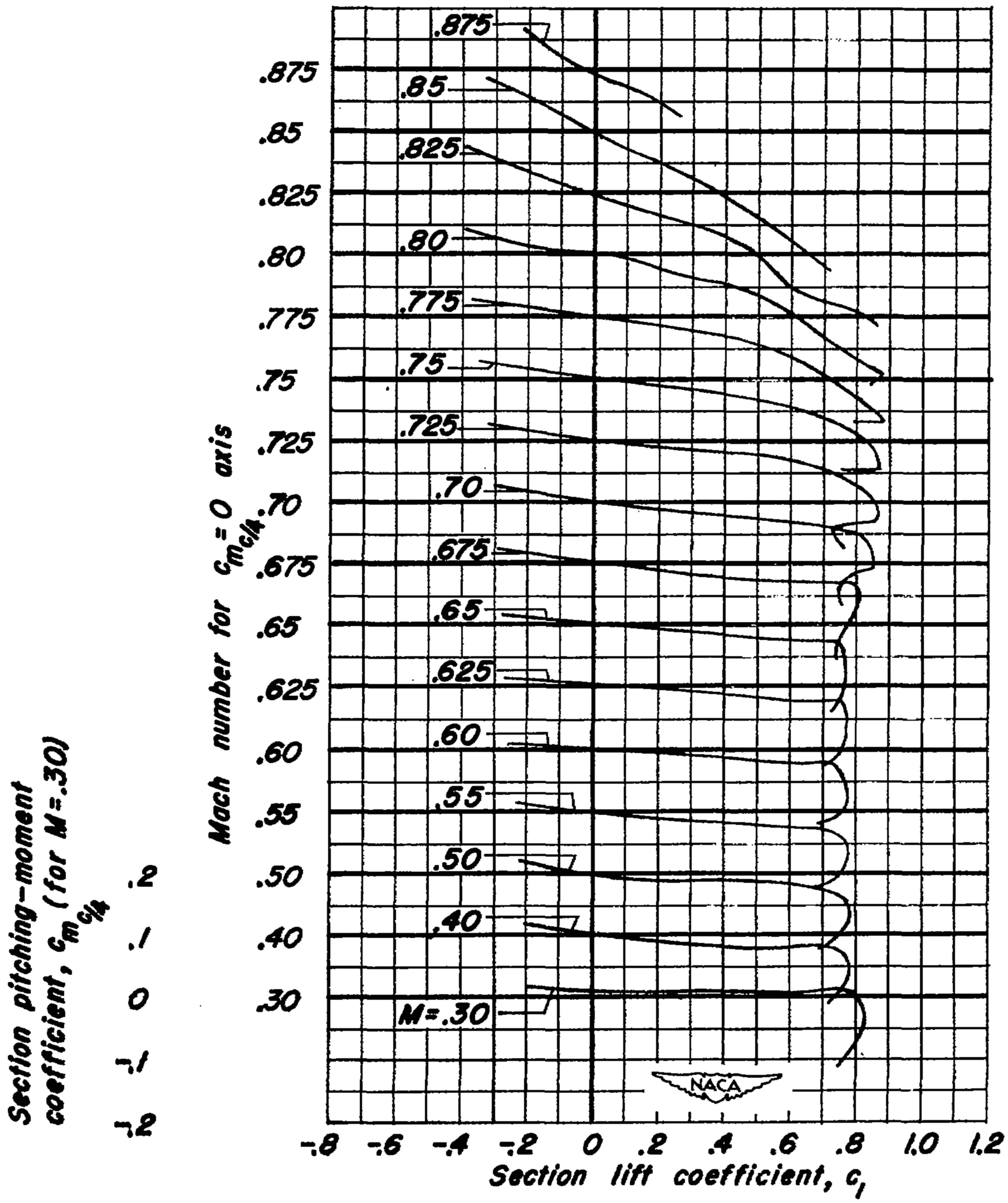
(a) NACA 64-010.

Figure 8.— The variation of section drag coefficient with section lift coefficient at various Mach numbers.



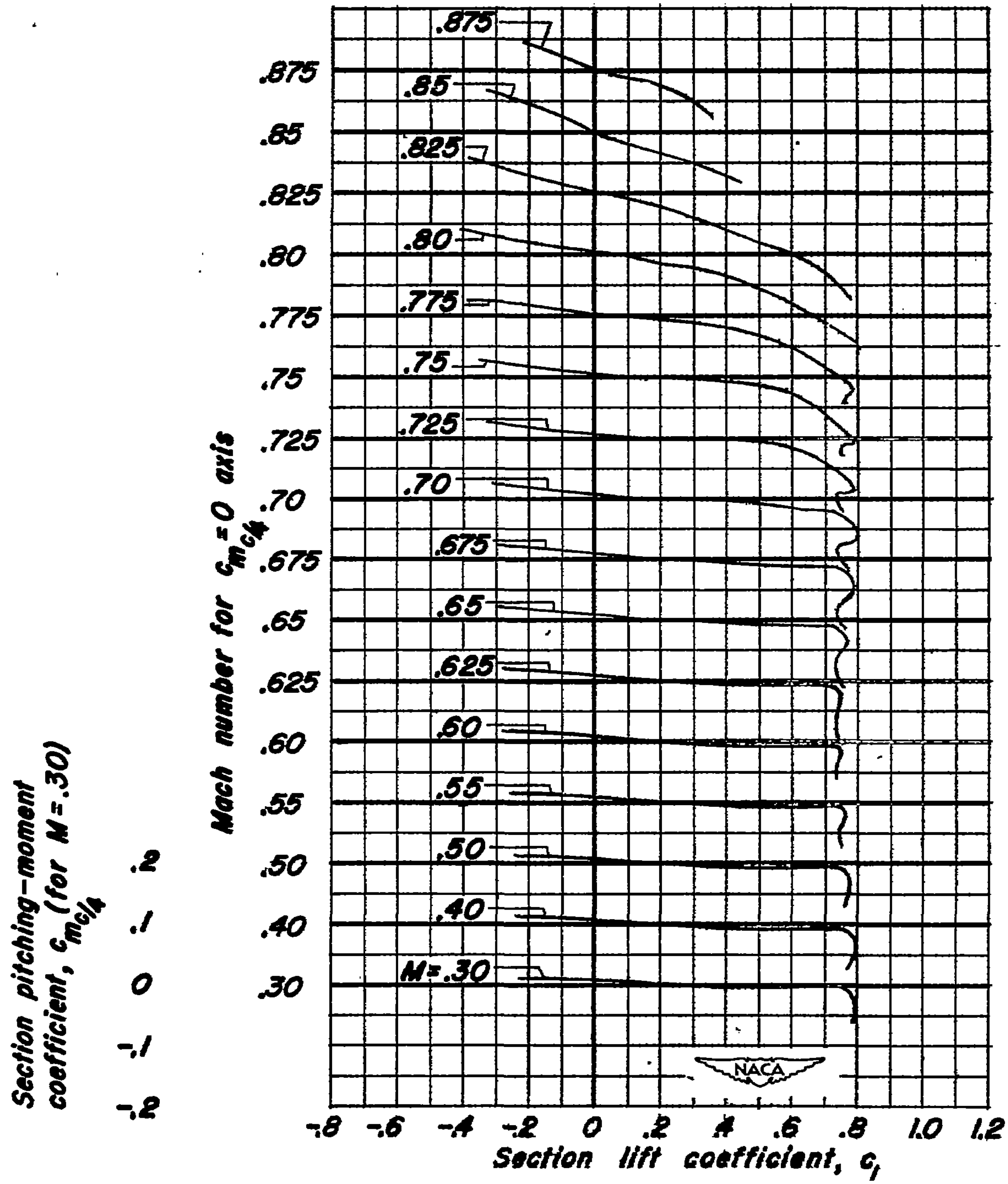
(b) NACA 64A010.

Figure 8. – Concluded.



(a) NACA 64-010.

Figure 9. — The variation of section pitching-moment coefficient with section lift coefficient at various Mach numbers.



(b) NACA 64A010.

Figure 9. — Concluded.